VISIT…

49

Coatings for Nuclear Power Generating Stations

Edmond W. Jarret

Con/Chem, Inc.
Furlong, Pennsylvania

Protective coatings play a significant role in the safe and efficient operation of nuclear power plants. The manufacturing, application and documentation of coating materials used at these facilities are subject to rigid specifications and procedures to assure a high level of performance. While this chapter will include a discussion of surfacing cements and paints, materials may be referred to as coatings for the purpose of brevity.

Nuclear power plants can be divided into three areas for identification purposes. Class 1 areas include interior surfaces of Primary Containment; Class 2 areas include those surfaces outside of Primary Containment that are subject to exposure by radioactivity with traffic conditions, and chemical spills. Class 3 signifies "non-nuclear" areas.

OPERATING CONDITIONS

Two types of reactors are used to power these facilities. They are pressurized water reactors (PWRs) and boiling water reactors (BWRs).

Within Primary Containment, the environment created by the two types of reactors is similar and will vary according to the method of construction and the operation of the particular reactor. Under normal conditions, coatings within Primary Containment are subjected to a variety of conditions that are outlined in Table 49-1.

Some localized areas may receive higher than average doses of radiation, however. Examples would be fuel storage canals and areas adjacent to pipe assemblies. Table 49-2 outlines some typical areas.

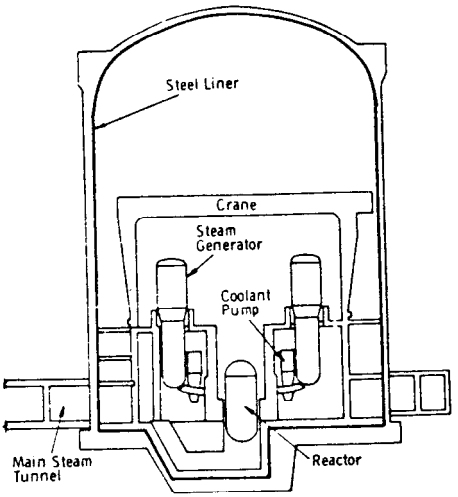

Figure 49-1: PWR pressure containment system. Chart by ANSI—see Reference 1.

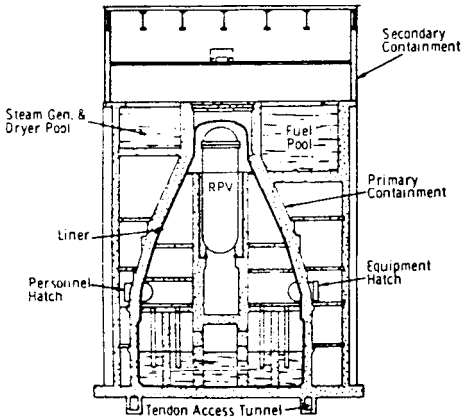

Figure 49-2: BWR Mark II over and under pressure suppression containment system. Chart by ANSI—see Reference 1.

Table 49-1: Typical Design Exposure Conditions of Coatings for Normal Operation of Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs)

Reactor Type	Atmosphere	Relative Humidity (%)	Temperature (°F)	Pressure (mm Hg)	Accumulated Radiation Exposure During 40 yr Life (rads)
PWR	Air or nitrogen	100	120	760*	5×10^6–3×10^9
BWR	Air or nitrogen	100	135-150	760	5×10^6–3×10^9

*1 atmosphere.

From table by ANSI—see Reference 1.

Table 49-2: Radiation Exposure Guide of Coatings for Normal Operation of Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs)

Nuclear Containment Facility or Area	General Level of Exposure During 40 yr* Life . . . . . (rads). . . . . Floor	Wall	Ceiling
(a) Containment structures	1×10^2	1×10^2	1×10^2
(b) Canals for fuel storage, examination, and handling	2×10^9–7×10^9	2×10^9–7×10^9	—
(c) Ductwork and filtration system	0.5×10^9–1×10^9	0.5×10^9	0.5×10^9

*It is not intended that a coating system initially applied to a reactor containment facility last for forty years without appropriate maintenance or overcoating.

From table by ANSI–see Reference 1.

In the event of a malfunction of the reactor or safety related equipment, a condition known as a Loss of Coolant Accident (LOCA) may occur within the Primary Containment Structure. Should this happen, the environment would become dramatically altered in a matter of seconds and result in the escalation of temperature and pressure to dangerous levels. To counteract this condition, large quantities of water with chemical additives are automatically directed onto all surfaces by means of high pressure spray systems.

A LOCA condition could severely damage conventional paint systems, causing them to disbond, combine with the spray solutions and clog the pump suction spray screens; thus jeopardizing the safe operation of the plant.

Qualified coatings, on the other hand, are formulated to resist these conditions and not peel or flake off in any sufficient quantity to affect the engineered safety systems.

Typical time/temperature/pressure LOCA curves are pictured below in Figures 49-3 and 49-4.

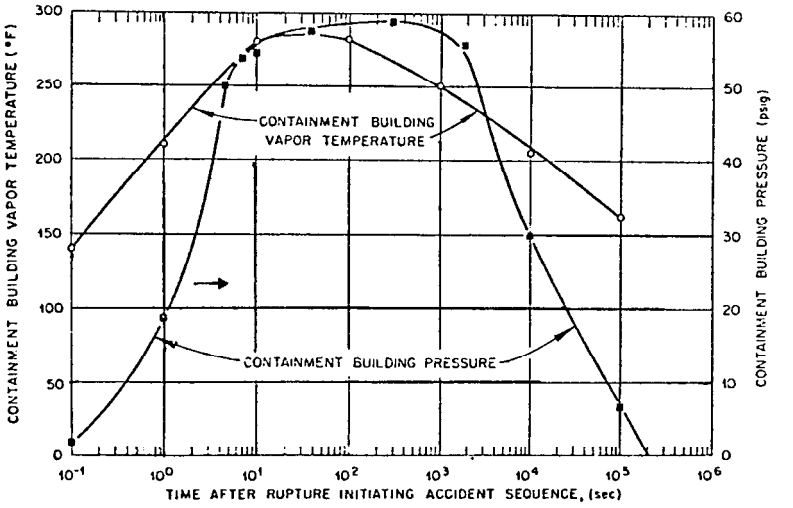

Figure 49-3: Typical curve for PWR containment facilities showing temperature and pressure vs time. Chart by ANSI–see Reference 1.

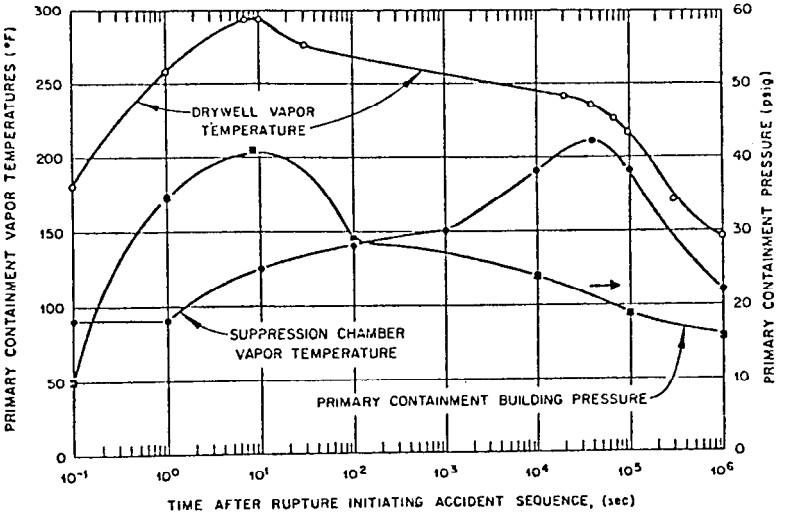
PRIMARY CONTAINMENT VAPOR TEMPERATURES (°F)
PRIMARY CONTAINMENT PRESSURE (psig)
DRYWELL VAPOR TEMPERATURE
SUPPRESSION CHAMBER VAPOR TEMPERATURE
PRIMARY CONTAINMENT BUILDING PRESSURE
TIME AFTER RUPTURE INITIATING ACCIDENT SEQUENCE, (sec)

Figure 49-4: Typical curve for BWR containment facilities showing temperature and pressure vs time. Chart by ANSI—see Reference 1.

Coatings in Class 2 areas are subjected to a variety of conditions which include abrasion and impact from fuel handling and other traffic operations, radioactive exposure, chemical attack and demineralized water immersion. Since personnel regularly service Class 2 areas, the coating systems must resist these conditions and be easily decontaminated to safe levels.

Coatings in Class 3 areas are formulated for architectural and wear properties. Conventional paint systems are generally used in these areas.

QUALIFICATION REQUIREMENTS

In order to qualify coatings for use in nuclear power plants, suppliers must prepare test specimens of the candidate systems and submit them to test agencies having equipment that can simulate Class 1 and 2 conditions. The Oak Ridge National Laboratories in Oak Ridge, Tennessee is one agency used by most suppliers.

Coating suppliers, contractors, equipment manufacturers, and inspection agencies wishing to do business in Class 1 and 2 areas must submit to thorough audits by the A/E firm in charge of the project or the owner. Personnel, equipment and Q/A programs are screened to see that they meet the requirements as set forth by the specification.Failure to comply is grounds for rejection.

In order to assure that the most qualified personnel are available for nuclear coating work, a program has been established to certify Registered Professional Engineers and nonregistered engineers, technicians and other personnel. This program was developed by, and is administered by, the National Board of Registration for Nuclear Safety Related Coating Engineers and Specialists, Box 1999, Sun City, Arizona 85372.

Several engineering societies play an instrumental role in developing standards, specifications and in dispensing useful information with regard to nuclear coating work. Typical are:

American National Standards Institute

American Society for Testing and Materials

Steel Structures Painting Council

National Association of Corrosion Engineers

COATING VARIETIES AND APPLICATION

Nuclear coatings are formulated to seal and protect concrete, concrete block and steel surfaces. The most commonly used coating types are the amine and polyamide cured epoxy systems. The solids, by volume, can vary from 50 to 100% with fillers or reinforcement fibers usually added so that the coating can perform a wide variety of functions. Reasons for their wide use are that they bond tenaciously to a variety of substrates; they cure to a hard smooth finish which results in superior decontamination qualities; and, most importantly, they perform satisfactorily in Class 1 and 2 service.

Inorganic zinc coating systems have been used quite frequently in certain defined areas such as structural steel, primary containment steel (i.e., Wetwell, Torus, exterior surfaces of pressure pipe, and some exterior steel equipment). One coat is all that is usually necessary, although some specifications call for two coats. Their main advantages are that they resist abrasion and provide cathodic protection for long term and superior resistance to weathering, especially along ocean coasts. They finish to a somewhat rough and porous surface and are occasionally topcoated with epoxies or urethanes, depending on the ultimate service conditions.

A class of coatings known as strippable coatings has been successfully used in Class 2 areas. These polymer materials are airless sprayed onto surfaces to provide a temporary barrier against radioactive contamination of the substrate. When saturated with contamination, the flexible material is pulled off of the surface by workmen and safely disposed of in 55 gallon drums. A new coat can then be applied.

Salt water intake tunnels, particularly along the southern coast, are subjected to biofouling. A class of toxic coatings known as organotins utilizes compounds of tin oxides and fluorides to retard the formation of barnacles, algae, etc. These coatings look quite promising.

Waterborne epoxy formulations have been used quite extensively in some nuclear facilities with good success. They have not yet met the requirements of Class 1 testing, but perform well in certain areas such as radwaste handling areas.

As is the case in all critical coating applications, strict environmental controls are required to permit the coating to bond and cure properly. Many specifications limit the temperature ranges from 50° to 100°F, and the surface and surrounding air temperatures to at least 5°F above the temperature where condensation will form (dew point). One exception to these restrictions would be the

inorganic zinc coatings that cure by hydrolysis. In this case condensation on the surface (dew) is desirable during the cure cycle.

In Class 3 areas, several types of coatings are used. They include alkyds, acrylic latexes, enamels, urethanes, and chlorinated rubbers.

Steel surfaces do not provide any unusual difficulties during coating operations, as long as the steel is of high quality and the environmental conditions are strictly controlled. Specifications usually call for an abrasive blast that meets Steel Structures Painting Council (SSPC) Spec. #5 ("white metal") finish; although steel to be used in non-nuclear areas usually receives an SSPC #10 ("near white") finish or an SSPC #6 ("commercial") finish. Areas that require special attention are welds, seams, edges, channels, etc.

Concrete, on the other hand, offers a variety of problems. In the pouring and placement of concrete walls, the formation of blowholes or voids is inevitable. These imperfections vary in size and quantity by the way the concrete is placed and compacted. If the immersion vibrators are kept just below the surface of the concrete during the pour and raised at the same rate as the concrete, the formation of blowholes is kept under reasonable control. In actual practice, this procedure is difficult to control; thus causing a variety of patterns and textures to appear from one pour to the next. Figure 49-5 shows a variety of blowhole patterns.

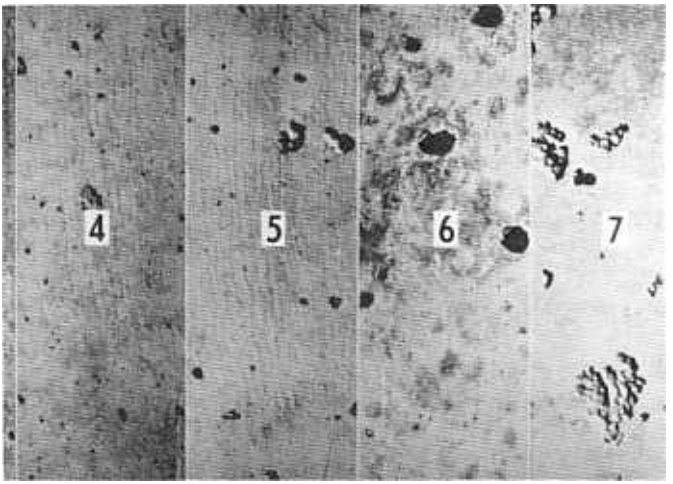

Figure 49-5: Blowhole patterns. Photo by Concrete Society–see Reference 5.

Other contributing factors to the quality of the concrete finish are the types of forms and the release agents used; the type of mix and aggregates used and the ambient temperature. The improper placement of forms can result in significant offsets of ½ to 1" or more as well as fins and projections.

Since Class 1 and 2 surfaces must be easily decontaminated to safe levels, these imperfections must be corrected. The offsets, fins and projections are usually repaired by masons using stones and grinding wheels. The blowholes are corrected by application of the coating materials.

Figure 49-6: A coating applicator is shown spraying epoxy coatings on Class 2 walls and floors. Photos by Con/Chem, Inc.

Some coating suppliers have responded by increasing the volume solids to 90% or higher and adding fillers and/or fibers to arrive at a family of materials commonly referred to as surfacing cements.

Applicators apply these products by one or more methods including spraying, rolling, troweling, squeegeeing and brushing. The materials can be made to partially fill the blowholes; however, in fact, they actually bridge rather than fill these voids. It is important to note that no applicator can guarantee a 100% void-free surface without considerable expense and delays; therefore the prudent and realistic specifying engineer will use such words as "essentially" void-free and include some specific statement on the maximum number and size of permissable voids in the finished film per area (50, 100, or 150 sq. ft., etc.).

In order to minimize surface preparation, concrete surfaces are usually water cured for 28 days; however, the use of curing agents cannot be altogether avoided; so special care must be taken to assure the selected agent is compatible with the coating used.

When selecting form release agents, the lacquer or epoxy types are usually used as they remain on the forms when the forms are pulled and do not contaminate the concrete. (Under most circumstances, oils are not used as they will detrimentally affect the bonding characteristics of the coating to the substrate; however, some suppliers claim their oils degrade with time and leave a clean surface.)

Hard troweled floor surfaces are usually broom finished to provide a surface profile and to eliminate costly abrasive blasting. Some abrasive blasting will be required on the typical job; however. The use of muriatic acid etching is prohibited on nuclear sites due to the adverse effect of chlorides on stainless steel.

INSPECTION

Highly trained and qualified inspectors are required to monitor and record all coatings work. This practice is designed to assure the utility owner that the coating system was applied in accordance with the provisions of the specification.

Items such as material storage, handling and application, surface preparation, mil thickness tests, environmental conditions, surface defects in the coating film and coating adhesion are all checked and recorded. Inspectors have the authority to halt work not being performed properly, and they can reject completed work that does not meet the requirements of the specification.

The importance of an effective inspection program cannot be over emphasized as the ultimate beneficiary of a safe and efficient operating nuclear power plant is the general public.

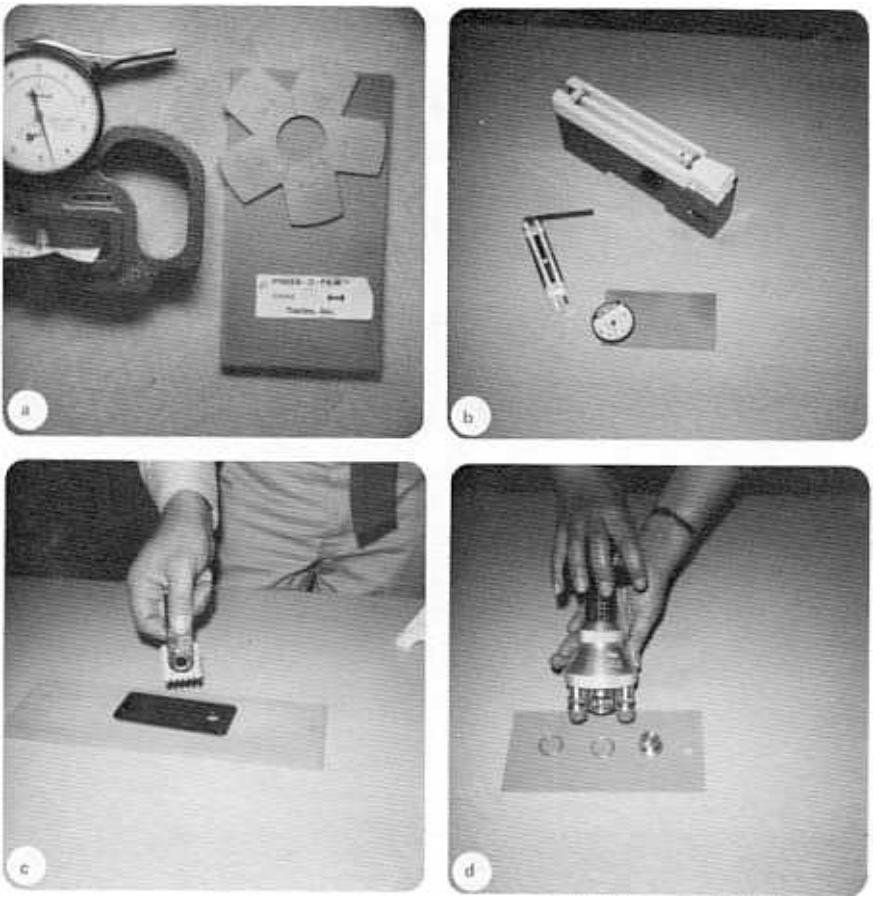

Figure 49.7: (a) Steel surface profile monitoring equipment; (b) Dew point monitoring equipment; (c) Wet film thickness gauge; (d) Elcometer adhesion tester. Photos by Metalweld, Inc.

REFERENCES

1. *Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities,* American National Standards Institute, New York, NY (1972).
2. *Manual of Coating Work for Light Water Nuclear Power Plant, Primary Containment and Other Safety Related Facilities*, American Society for Testing and Materials, Philadelphia, PA, Edition 1 (1979).
3. Rittenhouse, R.C., Protective Coatings for Power Plants, *Power Engineering*, pp. 30-38 (December 1982).
4. Berger, Dean, M., Gilbert Associates, Inc., Reading, PA, Preparing and Painting Vertical Concrete Surfaces of Buildings, a Paper for a Symposium in Finland (August 1977).
5. Thompson, M.S., Blowholes in Concrete Surfaces, *Concrete, The Journal of the Concrete Society*, Great Britain, Vol. 3 (February 1969).
6. Conversations with: B.W. Chandler and S.J. Oechsle of Metalweld, Inc., Philadelphia, PA and C.H. Holl, KTA-Tator, Inc., Houston, TX.